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(54) Method of making alkoxyated organosilicone resins

Verfahren zur Herstellung von alkoxyliertem Polyorganosiloxanharz

Procédé de préparation de résine polyorganosiloxane alcoxylée

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Description

[0001] The present invention is a method of making alkoxyated organosilicone resins and a method for introduction of various functional and nonfunctional groups into these resins.

[0002] As used herein, the term "resin" describes a silicone composition wherein the molecular structure is arranged in a predominantly three dimensional network. Thus, silicone "resin" distinguishes the composition from silicone fluids, which are predominantly a linear structure, and from silanes. The silicone resins utilized as starting material in the present invention are macromolecular polymers comprised primarily of $R_3SiO_{1/2}$ and $SiO_{4/2}$ siloxy units, wherein R is a functional or non-functional organic radical. Such units are conventionally called M and Q units, respectively.

[0003] Those skilled in the art will appreciate that such resins may also include a limited number of $R_2SiO_{2/2}$ and $RSiO_{3/2}$ siloxy units, conventionally referred to as D and T units, respectively. Generally speaking, the term "MQ resin" is used to describe organosilicone resins wherein the quantity of T and D units does not, on average, exceed 20 mole percent. Thus, organosilicone resins that primarily comprise M and Q units are frequently referred to as MQ resins.

[0004] MQ organosilicone resins may be produced by the methods disclosed in US-A-2,676,182. The MQ resins of said patent are produced by the acid hydrolysis of a silicate, which is subsequently end-capped by reaction with a trialkylhalosilane or hexamethyldisiloxane. Thus, these MQ resins are described by the empirical formula $[R_3SiO_{1/2}]_a[R_2SiO_{2/2}]_b[RSiO_{3/2}]_c[SiO_{4/2}]_d$ wherein R is a methyl or OH group and a, b, c and d are zero or positive numerical values, with the provisos that $a + b + c + d = 1$, $0 \leq (b + c) \leq 0.2$ and the ratio of $a:(b+c+d)$ is between 0.3 and 1.0.

[0005] US-A-5,352,751 describes the modification of linear dihydroxydiorganopolysiloxanes by reacting the residual silanol units with an alkoxy silane under mild temperatures (25°C) and relatively low ratios of alkoxy silane/alcohol to the polyorganosiloxane to provide straight-chain diorganopolysiloxanes.

[0006] US-A-5,091,484 is directed to elastomer forming compositions comprising an α,ω hydroxyl, trialkoxy or alkylene-trialkoxo end-blocked polydiorganosiloxane, MQ silicone resins having tetrafunctional SiO_2 -units and monovalent units and a titanium catalyst.

[0007] From EP-A-628 615 a composition comprising a combination of MQ resin and liquid polyorganosiloxanes is known. The reaction of residual silanol groups of the MQ resin with silanes, however, requires the presence of a condensation catalyst such as tetrabutyl titanate. Pretreatment of MQ resins with a silane, particularly methoxytrimethylsilane, disiloxane or disilazane is disclosed.

[0008] Most often, MQ resins have a number average molecular weight, M_n , between 2,200 and 7,000 and are

prepared and sold in solution. When M_n is less than 2,200, these resins retain the characteristics of a liquid, regardless of whether or not they are removed from solution. When M_n is greater than 7,000, these resins are relatively insoluble in the preferred solvents. Likewise, when the ratio of $a:(b+c+d)$ is less than 0.3, M_n is typically greater than 7,000 and when the ratio is greater than 1.0, M_n is usually less than 2,200.

[0009] Those skilled in the art will also appreciate that end-capping a silicate hydrolyzate with a trialkylhalosilane or hexamethyldisiloxane renders a resin which has a substantial quantity of residual -OH groups associated therewith (often termed residual silanol). Such residual silanol groups are properly designated as T units. It is known in the art to lower the amount of residual silanol by further reaction of the resin with hexamethyldisilazane. Thus, as used herein, the term "MQ resin" also includes resins having either substantial residual silanol groups or reduced residual silanol.

[0010] It is also known that, of the residual silanol groups associated with MQ silicone resin, only a portion thereof are considered to be non-sterically hindered and thus capable of further reaction. Prior art methods are thus limited in that the degree of alkoxy functionality which is obtained is restricted by the concentration of non-sterically hindered residual silanol.

[0011] MQ resins made in accordance with US-A-2,676,182 are frequently described as being "benzene soluble". In reality, such resins are also soluble in a number of nonaromatic and aromatic organic solvents, including xylene and toluene. It is, however, also known to provide MQ resins in the form of spray-dried powders, as taught, in US-A-5,324,806.

[0012] MQ resins have a variety of uses. They are frequently blended with silicone fluids in the manufacture of silicone pressure sensitive adhesives and rubbers. Therein, it is known to cross-link the silicone fluids and resin with a cross-linking compound that reacts with functional groups associated with both the resin and fluid. Often the non-sterically hindered residual silanol groups associated with the resin serve as the functional groups. It is also known, however, to introduce functional groups, for example vinyl, by treating the resin with dimethylvinylchlorosilane.

[0013] Because of their versatile reactivity, alkoxyated organosilicone resins, whether or not they meet our definition of an MQ resin, are particularly useful as intermediate materials in the synthesis of silicone end-products, such as pressure sensitive adhesives.

[0014] Alkoxy functionality has been imparted to MQ resins by reacting the resin with an alcohol in the presence of a catalyst, such as tetrabutyl titanate. However, alkoxylation by this process is somewhat limited in that the degree of alkoxylation which is achieved is only 5 to 6 mole percent of the siloxy units. It is believed that this limit is due to the competing reaction involving intramolecular condensation of alkoxy sites.

[0015] The introduction of alkoxy functionality to MQ

resins has also been achieved via two other well-known methods which utilize reactions between alkoxy silanes and the non-sterically hindered residual silanol groups on the resin. Those skilled in the art will recognize that the two reactions are generally referred to as condensation and exchange, respectively. In the condensation reaction, an alcohol is produced in the formation of the Si-O-Si bond between the resin and silane. In the exchange reaction a direct substitution of the alkoxy group on the silane and the hydroxyl group on the resin will occur. Both reactions are usually performed in the presence of a catalyst, such as tetrabutyl titanate. The drawback of either approach is again the limited degree of alkoxylation which is achieved.

[0016] Thus, it is highly desirable to provide a process for incorporating alkoxy functionality into an organosilicone resin, wherein the degree of alkoxylation of said resin is not so limited as in the prior art.

[0017] It is therefore an object of the present invention to provide a method making an alkoxyated organosilicone resin wherein a higher degree of alkoxylation, as compared to prior art methods, is obtained.

[0018] In our present invention, there is provided a novel method of making an alkoxyated organosilicone resin, which method overcomes the drawbacks of the prior art. Our method of this invention comprises:

(I) reacting under conditions of reflux (A) an MQ organosilicone resin of the empirical formula $[R_3SiO_{1/2}]_a[R_2SiO_{2/2}]_b[RSiO_{3/2}]_c[SiO_{4/2}]_d$ wherein each R is independently a methyl or hydroxyl group and a, b, c and d are zero or positive numerical values with the provisos that $a + b + c + d = 1$, $0 \leq (b + c) \leq 0.2$ and the ratio of $a:(b+c+d)$ is between 0.3 and 1.0 dissolved in a solvent; and

(B) at least one alkoxy silane selected from the group consisting of silanes having the empirical formula $R_xSi(OR')_{(4-x)}$ wherein x is 1, 2 or 3, R is a monovalent radical in which R groups are independently selected from the group consisting of alkyl, alkenyl, aryl, arylalkyl, epoxy, ether, alkylamide, alkylamine and each OR' is an alkoxy group; in the presence of

(C) a catalytic amount of a basic catalyst, to produce an alkoxyated organosilicone resin;

(II) thereafter neutralizing the basic catalyst (C) by adding an acid to the reaction product of components (A), (B), and (C), and

(III) separating the alkoxyated resin from the remaining reaction products.

[0019] In a preferred embodiment, an alcohol component (D) is included in the reacting step (I). In the most preferred embodiment, the alcohol (D) is of the general formula HOR', wherein the OR' group is as defined above, and the alcohol (D) and alkoxy silane (B) have identical OR' groups.

[0020] The method allows a making of an alkoxyated

organosilicone resin which utilizes an MQ resin and a monoalkoxysilane.

[0021] It is a feature of this method that additional desirable organic groups, such as phenyl groups, along with the alkoxy groups, are incorporated into alkoxyated organosilicone resins.

[0022] It is another feature of this method that the number average molecular weight, Mn, and the weight average molecular weight, Mw, of our alkoxyated organosilicone resins are less than that of the starting MQ resin.

[0023] Component (A) of this invention is an MQ organosilicone resin of the empirical formula $[R_3SiO_{1/2}]_a[R_2SiO_{2/2}]_b[RSiO_{3/2}]_c[SiO_{4/2}]_d$ wherein each R is independently a methyl or hydroxyl group and a, b, c and d are zero or positive numerical values, with the provisos that $a + b + c + d = 1$, $0 \leq (b + c) \leq 0.2$ and the ratio of $a:(b+c+d)$ is between 0.3 and 1.0.

[0024] As previously mentioned, MQ resins may also contain a limited number of D and/or T units. Thus, the value of parameters a, b, c and d are limited as set forth above such that the number of D and/or T units does not exceed 20 mole percent of the number of siloxy units.

[0025] Furthermore, the above limitations dictate that the number of M units must be greater than at least 0.3 of the sum of the number of D, T and Q units. The ratio of M units to the sum of D, T and Q units is inversely proportional to the molecular weight of the resin. Thus, when the ratio of $M:(D+T+Q)$ is greater than 1.0, the MQ resin behaves more as a liquid than a solid. Hence, when that ratio is in excess of 1.0, Mn of the resin is generally less than 2,200. Conversely, when that ratio is less than 0.3, Mn generally exceeds 7,700 and the resin loses its solubility in the preferred solvents.

[0026] Component (B) of the invention is at least one alkoxy silane selected from the group of silanes having the empirical formula $R_xSi(OR')_{(4-x)}$ wherein x is 1, 2 or 3, R is a monovalent radical, which R groups are independently selected from the group consisting of alkyl, alkenyl, aryl, arylalkyl, epoxy, ether, alkylamide and alkylamine and each OR' is an alkoxy group. Because of availability, cost and reactivity, methoxy or ethoxy silanes are the most preferred.

[0027] It is important to note that component (B) herein does not include tetra alkoxy silanes. It was found that when a pure tetra alkoxy silane, such as tetra methoxy silane, was reacted with the MQ resins of component (A) in the presence of (C), a basic catalyst, the system had a tendency to produce an intractable precipitate. Those skilled in the art will recognize, however, that the use of a limited amount of a tetra alkoxy silane in combination with either mono-, di- or trialkoxy silanes is not specifically excluded in the practice of the present invention, except to the extent that such inclusion leads to an unacceptable quantity of intractable precipitate.

[0028] It is also important to note that component (B), the alkoxy silane, is used to introduce other radical

groups, in addition to alkoxy groups, into the structure of our organosilicone resin. Therefore, groups that are independently selected from the group consisting of alkyl, alkenyl, aryl, arylalkyl, epoxy, ether, alkylamide and alkylamine can be incorporated into the resin.

[0029] While not wishing to be bound to any particular theory for the chemical mechanism of this invention, it is demonstrated in the examples below that the formation of our alkoxyated organosilicone resin is augmented by the presence of an alcohol (D). When no intentional additions of alcohol are used in combination with an MQ resin, it is believed that the OR' groups of the alkoxy silane (B) react with the sterically unhindered hydroxyl groups of the resin to form such alcohol. Accordingly, the method of this invention is practiced with or without intentional additions of alcohol (D) in (I) the reacting step. It is believed, however, that the combination of an alkoxy silane and an alcohol aid in the alkoxylation and it is the preferred method of practicing our invention. In our most preferred method, the OR' groups of the alkoxy silane are identical to the OR' groups of the alcohol.

[0030] Component (C) of the invention comprises a catalytic amount of a basic catalyst. Suitable basic catalysts include NaOH, KOH, NaOCH₃, LiOH, potassium tertiary butoxide, LiOCH₃, KOCH₃, sodium silanolate and amines, such as ethanolamine or quaternary ammonium salts, such as tetrabutylammonium fluoride. It is noted that the amines and ammonium salts above will serve to catalyze the reaction of the invention, but at a considerably slower rate when compared to the remaining aforementioned basic catalysts.

[0031] As used herein, the term "catalytic amount" is that amount of catalyst which causes the reaction of our invention to proceed at a predetermined rate. The catalytic amount of catalyst will, of course, depend upon the type of basic catalyst, as some are more effective than others and the temperature at which the reaction is conducted.

[0032] The amount of catalyst may be from 0.01 to 2.5 parts by weight, preferably from 0.05 to 2.0 parts by weight per 100 parts by weight of the alkoxy silane.

[0033] The reacting step (I) is carried out under conditions of reflux. The reaction will proceed at room temperature conditions, but it is well-known in the art that reaction rates are accelerated at elevated temperatures. The MQ resin, as dissolved in an organic solvent, may be directly reacted. In one embodiment, a volatiles trap is employed which then substantially separates the alcohols and volatile reaction products from the alkoxyated resin.

[0034] We have found that if large amounts of component (C), the basic catalyst, or if small amounts (either generated or added) of component (D), the alcohol, are employed, the reaction tends to produce varying amounts of an intractable precipitate. Conversely, employing lower levels of the basic catalyst (C) and greater amounts of alcohol (D) tends to reduce and even sup-

press the formation of intractable precipitates. The absolute quantities of components (C) and (D) depend, of course, on the quantity of MQ resin being processed, the particular catalyst (C) and alcohol (D) which are employed.

[0035] The neutralizing step (III) is easily carried out by the introduction of an acid, such as dry ice or acetic acid, to the reaction mixture, after the reacting step (I). Carbon dioxide is particularly useful in this regard as any excess will simply leave the reaction mixture in the form of a vapor. Other useful neutralizing agents include chlorosilanes.

[0036] In the following examples, an alkoxyated organosilicone was produced in accordance with the present invention. In each example, the starting MQ resin (hereinafter "RES1") was dissolved in xylene at a concentration of 74 weight %. All weights of RES1 herein refer to the combined weight of the resin and the xylene solvent. Nuclear magnetic resonance (²⁹Si and ¹³C NMR) and silicone resin-calibrated gel permeation chromatography (GPC) were used to determine the general formula and molecular weight of RES1. The general formula comprised 43 mole% M units of (CH₃)SiO_{1/2}; 12 mole% T units of (OH)SiO_{3/2}; and 45 mole% Q units of SiO_{4/2}. The number average molecular weight, Mn, was 4,549 and the weight average molecular weight, Mw, was 17,760.

[0037] Those skilled in the art will appreciate that the "T" units reported above and below normally include a minor amount of sterically-hindered isopropoxy groups which result from the RES1 synthesis. As reported herein, that minor amount of isopropoxy groups is ignored.

Example 1

[0038] A solution of 89% pure trimethylmethoxysilane was prepared by reacting two moles of methanol with two moles of hexamethyldisilazane and by then distilling off the trimethylmethoxysilane formed therefrom. 150 g of RES1 and 1.5 g of a solution of 25 weight % sodium methoxide basic catalyst, dissolved in methanol, were added to 150 g of the 89% pure trimethylmethoxysilane in a flask. The reaction mixture was heated to reflux (75°C.) for 17 hours. Thereafter, the flask was fitted with a Dean Stark trap and the reaction mixture again heated to 135°C. until the collected volatiles remained constant. 135 g of volatiles were collected in the trap. After cooling, the trap was removed and 1.5 g of trimethylchlorosilane was thoroughly blended with the reaction mixture to inactivate the sodium methoxide catalyst. The resulting composition was filtered through a mixture of sodium bicarbonate and diatomaceous earth (to remove the Na-Cl formed upon catalyst inactivation) yielding a clear filtrate. The filtrate was devolatilized in a vacuum chamber at 0.67 kPa (5mm Hg) and 80°C., thus producing 102 g of dry powder. GPC and NMR testing revealed that the resulting organosilicone resin had a general formula comprised of: 47.82 mole % M units of (CH₃)SiO_{1/2}; 2.72

mole % T units of $(\text{CH}_3\text{O})\text{SiO}_{3/2}$; and 48.93 mole % Q units of $\text{SiO}_{4/2}$. The number average molecular weight, Mn, was 2,977 and the weight average molecular weight, Mw, was 5,086.

Example 2

[0039] 100 g of propyltrimethoxysilane were combined with 200 g of RES1 and 0.75 g of a solution of 25 weight % sodium methoxide basic catalyst, dissolved in methanol. The reaction mixture was heated at reflux (75°C.) for 5 hours. Thereafter, a solid piece of carbon dioxide was added to the reaction mixture to inactivate said catalyst. The mixture was filtered and devolatilized as described above, yielding 188 g of a clear, viscous fluid. GPC and NMR testing showed that the resulting alkoxyated organosilicone resin had a general formula comprised of: 25.08 mole % M units of $(\text{CH}_3)_3\text{SiO}_{1/2}$; 3.63 mole % M units of $(\text{CH}_3\text{O})_2(\text{CH}_3)\text{SiO}_{1/2}$; 1.09 mole % M units of $(\text{CH}_3\text{O})_3\text{SiO}_{1/2}$; 10.7 mole % D units of $(\text{CH}_3\text{O})(\text{CH}_3)\text{SiO}_{2/2}$; 6.02 mole % D units of $(\text{CH}_3\text{O})_2\text{SiO}_{2/2}$; 12.02 mole % T units of $(\text{CH}_3)\text{SiO}_{3/2}$; 15.91 mole % T units of $(\text{CH}_3\text{O})\text{SiO}_{3/2}$; and 25.39 mole % Q units of $\text{SiO}_{4/2}$. The number average molecular weight, Mn, was 2,338 and the weight average molecular weight, Mw, was 8,940.

Example 3

[0040] 60 g of phenyltrimethoxysilane, 200 g of RES1 and 2.25 g of a solution of 25 weight % sodium methoxide basic catalyst, dissolved in methanol were combined and heated at 145°C. under a Dean-Stark trap for six hours. 18 g of volatiles were collected in the trap. 3 g of trimethylchlorosilane were then added to the reaction mixture to neutralize the basic catalyst. The resulting mixture was then filtered and devolatilized as described above, yielding 198 g of a clear liquid. GPC and NMR testing showed that the resulting alkoxyated organosilicone resin had a general formula comprised of: 36.46 mole % M units of $(\text{CH}_3)_3\text{SiO}_{1/2}$; 1.90 mole % M units of $(\text{CH}_3\text{O})_2(\text{Ph})\text{SiO}_{1/2}$; 0.45 mole % M units of $(\text{CH}_3\text{O})_3\text{SiO}_{1/2}$; 5.25 mole % D units of $(\text{CH}_3\text{O})(\text{Ph})\text{SiO}_{2/2}$; 3.57 mole % D units of $(\text{CH}_3\text{O})_2\text{SiO}_{2/2}$; 6.67 mole % T units of $(\text{Ph})\text{SiO}_{3/2}$; 12.29 mole % T units of $(\text{CH}_3\text{O})\text{SiO}_{3/2}$; and 33.31 mole % Q units of $\text{SiO}_{4/2}$, where Ph represents a phenyl group. The number average molecular weight, Mn, was 2,110 and the weight average molecular weight, Mw, was 4,907.

Example 4

[0041] 100 g of RES1, 65 g of methyltriethoxysilane and 0.5 g of a solution of 25 weight % sodium methoxide basic catalyst dissolved in methanol, were combined and heated at 135°C under a Dean-Stark trap for 17 hours. 10 ml of volatiles were collected in the trap. 1.5 g of trimethylchlorosilane were then added to the reac-

tion mixture to neutralize the basic catalyst. The resulting mixture was then filtered and devolatilized as described above, yielding 105 g of a clear liquid. GPC and NMR testing showed that the resulting alkoxyated organosilicone resin had a general formula comprised of: 36.89 mole % M units of $(\text{CH}_3)_3\text{SiO}_{1/2}$; 0.53 mole % M units of $(\text{CH}_3)(\text{EtO})_2\text{SiO}_{1/2}$; 0.85 mole % M units of $(\text{EtO})_3\text{SiO}_{1/2}$; 6.04 mole % D units of $(\text{CH}_3)(\text{EtO})\text{SiO}_{2/2}$; 3.23 mole % D units of $(\text{EtO})_2\text{SiO}_{2/2}$; 10.9 mole % T units of $(\text{CH}_3)\text{SiO}_{3/2}$; 12.75 mole % T units of $(\text{EtO})\text{SiO}_{3/2}$; and 28.61 mole % Q units of $\text{SiO}_{4/2}$, where Et represents an ethyl group. The number average molecular weight, Mn, was 1,457 and the weight average molecular weight, Mw, was 4,912.

Example 5

[0042] This example was prepared to show that LiOH is also an effective catalyst to carry out the method of our invention. 200 g of RES1, 200 g of methyltrimethoxysilane and 1.0 g of a solution of 10 weight % LiOH.H₂O basic catalyst, dissolved in methanol, were combined and heated at 100°C. under a Dean-Stark trap for 16 hours, until the collected volatiles remained constant. Thereafter, a solid piece of carbon dioxide was added to the reaction mixture to inactivate the basic catalyst. The mixture was not filtered and devolatilized as described above and included a small quantity of unreacted methyltrimethoxysilane. GPC and NMR testing detected that the resulting alkoxyated organosilicone resin had a general formula which included M units of $(\text{CH}_3)\text{SiO}_{1/2}$; M units of $(\text{CH}_3\text{O})_2(\text{CH}_3)\text{SiO}_{1/2}$; M units of $(\text{CH}_3\text{O})_3\text{SiO}_{1/2}$; D units of $(\text{CH}_3\text{O})(\text{CH}_3)\text{SiO}_{2/2}$; D units of $(\text{CH}_3\text{O})_2\text{SiO}_{2/2}$; T units of $(\text{CH}_3)\text{SiO}_{3/2}$; T units of $(\text{CH}_3\text{O})\text{SiO}_{3/2}$; and Q units of $\text{SiO}_{4/2}$ in indeterminate mole percents. The number average molecular weight, Mn, was 1,037 and the weight average molecular weight, Mw, was 7,600.

Comparative Example

[0043] In a known manner, an MQ resin having a drastically reduced sterically-unhindered residual silanol content, was prepared by heating an MQ resin solution (of the RES1 formulation) under conditions of reflux and in the presence of KOH. GPC and NMR testing showed that this MQ resin had a general formula comprised of: 42.77 mole% M units of $(\text{CH}_3)_3\text{SiO}_{1/2}$; 2.90 mole% T units of $(\text{OH})\text{SiO}_{3/2}$; and 54.32 mole% Q units of $\text{SiO}_{4/2}$. In the MQ resin, Mn was 5,143 and Mw was 13,950. The treated resin was dissolved in a xylene solution at 50 weight% solids.

[0044] 200 g of the treated resin solution, 100 g of 89% pure trimethylmethoxysilane and 0.25 g of anhydrous sodium methoxide powder were heated to reflux at 60°C. for 16 hours. Thereafter, a solid piece of carbon dioxide was added to the reaction mixture to inactivate the basic catalyst. The mixture was filtered and devola-

tilized as described above, yielding a solid powder. GPC and NMR testing showed that the resulting organosilicone resin so-treated had a general formula comprised of: 43.18 mole% M units of $(\text{CH}_3)_3\text{SiO}_{1/2}$; 3.79 mole% T units of $(\text{OH})\text{SiO}_{3/2}$; and 52.93 mole% Q units of $\text{SiO}_{4/2}$. Mn was 4,892 and Mw was 13,010.

[0045] Accordingly, it appears that virtually no reaction occurred between the MQ resin and the monoalkoxy silane.

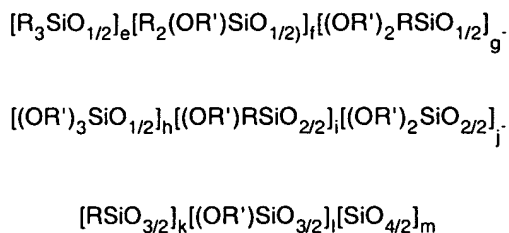
Example 6

[0046] The identical reaction set forth in the Comparative Example was repeated except that 15 g of methanol were added to the reaction mixture before refluxing. GPC and NMR testing showed that the resulting organosilicone resin had a general formula comprised of: 47.11 mole% M units of $(\text{CH}_3)_3\text{SiO}_{1/2}$; 0.55 mole% D units of $(\text{OCH}_3)_2\text{SiO}_{2/2}$; 6.02 mole% T units of $(\text{OCH}_3)\text{SiO}_{3/2}$; and 46.12 mole% Q units of $\text{SiO}_{4/2}$. Mn was 3,338 and Mw was 7,714.

[0047] Thus, it is clear that the employment of methanol in the reaction step promoted the formation of an alkoxyated organosilicone resin from a MQ resin, which had been treated to have an extremely low residual sterically-unhindered silanol concentration. It should be noted that this alkoxylation was conducted using a monoalkoxy silane in combination with the methanol.

[0048] In each of Examples 1 - 6, an alkoxyated organosilicone resin was successfully made from an MQ resin by employment of the method of our claimed invention. It is also clear therefrom that our method may utilize mon-, di- and trialkoxy silanes. It is further clear that any number of basic catalysts can be employed and that our method can be used to incorporate other organic groups, such as phenyl groups, into an organosilicone resin.

[0049] Thus, the alkoxyated organosilicone resin compositions produced by our method are comprised of siloxy groups according to the following the empirical formula



wherein each OR' is an alkoxy radical, which alkoxy radicals may be the same or different; each R radical is a monovalent hydrocarbon radical independently selected from the group consisting of alkyl, alkenyl, aryl, arylalkyl, epoxy, ether, alkylamide, alkylamine and hydroxyl radicals; and e, f, g, h, i, j, k, l and m are zero or positive numerical values, with the proviso that $e + f + g + h + i$

$$+ j + k + l + m = 1.$$

[0050] In a preferred embodiment, our alkoxyated organosilicone resin has a higher degree of alkoxylation than was obtained by prior art methods. Accordingly, the preferred composition of this invention, independent of our claimed method, includes more than 6 mole percent of alkoxyated siloxy units. Thus, $f + g + h + i + j + l > 0.06$.

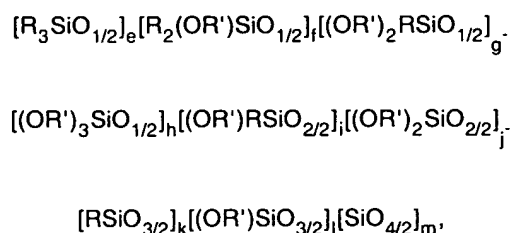
[0051] Surprisingly, our method is capable of producing organosilicone resins of the MDTQ-type having unusually high degrees of alkoxylation. In Example 2, for instance, 37 mole percent of the siloxy units are alkoxyated. The degree of alkoxylation can be engineered by varying the parameters of reaction time, concentration of reactants and temperature of reaction. Thus, our method permits the synthesis of novel alkoxyated organosilicone resin compositions wherein more than 10, 20 or 30 mole percent of the siloxy groups are alkoxyated.

[0052] Surprisingly, our claimed invention produces an alkoxyated organosilicone resin that has extremely low levels of residual silanol. As verified by proton NMR testing, we have also found that residual silanol levels in our resins are typically below detectable limits (i.e. less than two mole percent of siloxy units).

[0053] From the examples, it is further apparent that the method of our invention can be used to produce an alkoxyated organosilicone resin that has a lower Mn and Mw than the MQ resin starting material. Our method may then be characterized as having the ability to "digest" the MQ resin, while at the same time alkoxyating the composition. Thus, in another embodiment of the invention, the alkoxyated organosilicone resin is limited to that including at least 10 mole percent of siloxy units, of the sum of the T and Q type, to retain a substantially three dimensional macromolecular structure. This embodiment of the invention is best expressed in terms of the empirical formulation wherein $k + l + m \geq 0.10$.

Claims

1. A method of producing an alkoxyated organosilicone resin having siloxy groups according to the empirical formula



wherein each OR' is an alkoxy radical, which alkoxy radicals may be the same or different; each R radical is a monovalent radical independently selected from the group consisting of alkyl, alkenyl, aryl, arylalkyl, epoxy, ether, alkylamide, alkylamine and hy-

droxyl radicals; and e, f, g, h, i, j, k, l and m are zero or positive numerical values with the provisos that $e + f + g + h + i + j + k + l + m = 1$ and $f + g + h + i + j + l > 0.06$,

said method comprising the steps of:

(I) reacting under conditions of reflux,

(A) an MQ organosilicone resin of the empirical formula $[R_3SiO_{1/2}]_a[R_2SiO_{2/2}]_b[RSiO_{3/2}]_c[SiO_{4/2}]_d$ wherein each R is independently a methyl or hydroxyl group and a, b, c and d are zero or positive numerical values, with the provisos that $a + b + c + d = 1$, $0 \leq (b+c) \leq 0.2$ and the ratio of a: (b+c+d) is between 0.3 and 1.0, dissolved in a solvent;

(B) at least one alkoxy silane selected from the group consisting of silanes having the empirical formula $R_xSi(OR')_{(4-x)}$ wherein x is 1, 2 or 3, R is a monovalent radical, which R groups are independently selected from the group consisting of alkyl, alkenyl, aryl, arylalkyl, epoxy, ether, alkylamide, alkylamine and each OR' is an alkoxy group; in the presence of

(C) a catalytic amount of a basic catalyst to produce an alkoxyated organosilicone resin;

(II) thereafter neutralizing the basic catalyst by adding an acid to the reaction product of components (A), (B) and (C), and

(III) separating the alkoxyated resin from the remaining reaction products.

2. The method of claim 1 wherein said MQ organosilicone resin (A) has a number average molecular weight between 2,200 and 7,000.

3. The method of claim 2 wherein the alkoxyated organosilicone resin has a number average molecular weight that is less than the number average molecular weight of starting component (A).

4. The method of claim 1 further comprising the inclusion of a component (D), an alcohol, in said reacting step (I).

5. The method of claim 1 wherein said basic catalyst is selected from the group consisting of NaOH, KOH, $NaOCH_3$, LiOH, potassium tertiary butoxide, $LiOCH_3$, $KOCH_3$, sodium silanolate, ethanolamine and tetrabutyl ammonium fluoride.

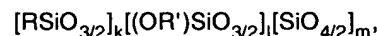
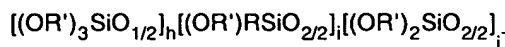
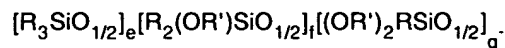
6. The method of claim 1 wherein said neutralization step (II) is carried out by adding a chlorosilane to the reaction product of components (A), (B) and (C).

7. The method of claim 4 further comprising the step of (III) removing said alcohol (D) during said reacting step (I).

8. The alkoxyated organosilicone resins obtainable by the method of claims 1-7.

Patentansprüche

1. Verfahren zum Herstellen von alkoxyliertem Organosiliconharz mit Siloxygruppen der empirischen Formel:



in der jedes OR' ein Alkoxyrest ist, wobei die Alkoxyreste gleich oder unterschiedlich sein können, jeder R-Rest ist ein einwertiger Rest, unabhängig ausgewählt aus der Gruppe, bestehend aus Alkyl-, Alkenyl-, Aryl-, Arylalkyl-, Epoxy-, Ether-, Alkylamid-, Alkylaminresten und Hydroxylgruppen, und e, f, g, h, i, j, k, l und m null oder positive Zahlenwerte sind, mit der Bedingung, daß $e + f + g + h + i + j + k + l + m = 1$ und $f + g + h + i + j + l > 0,06$ sind, wobei das Verfahren die Schritte aufweist:

(I) Umsetzen unter Rückflußbedingungen,

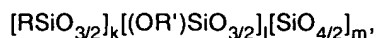
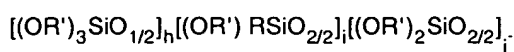
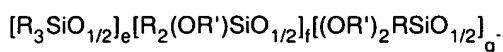
(A) ein in einem Lösemittel aufgelöstes MQ Organosiliconharz der empirischen Formel $[R_3SiO_{1/2}]_a[R_2SiO_{2/2}]_b[RSiO_{3/2}]_c[SiO_{4/2}]_d$, in der jedes R unabhängig ein Methylrest oder eine Hydroxylgruppe ist und a, b, c und d null oder positive Zahlenwerte sind, mit der Bedingung, daß $a + b + c + d = 1$, $0 \leq (b+c) \leq 0,2$ und das Verhältnis von a: (b+c+d) zwischen 0,3 und 1,0 ist, (B) mindestens ein Alkoxyasilan, ausgewählt aus der Gruppe, bestehend aus Silanen mit der empirischen Formel $R_xSi(OR')_{(4-x)}$, wobei x 1, 2 oder 3 ist, R ein einwertiger Rest ist, wobei die R-Reste unabhängig ausgewählt sind aus der Gruppe, bestehend aus Alkyl, Alkenyl, Aryl, Arylalkyl, Epoxy, Ether, Alkylamid, Alkylamin, und jedes OR' ist eine Alkoxygruppe, in Gegenwart

(C) einer katalytischen Menge eines basischen Katalysators, um ein alkoxyliertes Organosiliconharz herzustellen,

- (II) anschließendes Neutralisieren des basischen Katalysators durch Zugabe einer Säure zum Reaktionsprodukt der Bestandteile (A), (B) und (C) und
(III) Abtrennen des alkoxylierten Harzes von den restlichen Reaktionsprodukten. 5
2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das MQ Organosiliconharz (A) ein zahlenmittleres Molekulargewicht zwischen 2.200 und 7.000 aufweist. 10
3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß das alkoxylierte Organosiliconharz ein zahlenmittleres Molekulargewicht hat, das kleiner ist als das zahlenmittlere Molekulargewicht des Ausgangsbestandteils (A). 15
4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß im Reaktionsschritt (I) ein Bestandteil (D), ein Alkohol, mit verwendet wird. 20
5. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der basische Katalysator ausgewählt ist aus der Gruppe, bestehend aus NaOH, KOH, NaOCH₃, LiOH, Kalium-t-butoxid, LiOCH₃, KOCH₃, Natriumsilanolat, Ethanolamin und Tetrabutylammoniumfluorid. 25
6. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Neutralisationsschritt (II) ausgeführt wird durch Zugabe eines Chlorosilans zum Reaktionsprodukt der Bestandteile (A), (B) und (C). 30
7. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß weiterhin Schritt (III) das Entfernen des Alkohols (D) während des Reaktionsschrittes (I) umfaßt. 35
8. Alkoxylierte Organosiliconharze, erhältlich durch das Verfahren der Ansprüche 1-7. 40

Revendications

1. Un procédé de production d'une résine d'organosilicone alcoxylée ayant des groupes siloxy, répondant à la formule empirique



où chaque OR' est un groupe alcoxy, ces groupes alcoxy pouvant être identiques ou différents ; chaque radical R est un groupe monovalent choisi indépendamment dans la classe formée par les groupes alkyles, alcényles, aryles, arylalkyles, époxy, éthers, alkylamides, alkylamines et hydroxyle ; et e, f, g, h, i, j, k, l et m sont zéro ou des valeurs numériques positives, avec les conditions que $e + f + g + h + i + j + k + l + m = 1$ et $f + g + h + i + j + l > 0,06$, ledit procédé comprenant les étapes suivantes :

(I) faire réagir, dans des conditions de reflux,

(A) une résine d'organosilicone MQ ayant la formule empirique $[R_3SiO_{1/2}]_a [R_2SiO_{2/2}]_b [RSiO_{3/2}]_c [SiO_{4/2}]_d$ où chaque R est indépendamment un groupe méthyle ou hydroxyle et a, b, c et d sont zéro ou des valeurs numériques positives, avec les conditions que $a + b + c + d = 1$, $0 \leq (b+c) \leq 0,2$ et le rapport $a:(b+c+d)$ soit compris entre 0,3 et 1,0, dissoute dans un solvant ;
(B) au moins un alcoxsilane choisi dans la classe formée par les silanes ayant la formule empirique $R_xSi(OR')_{(4-x)}$ où x est 1, 2 ou 3, R est un radical monovalent, les radicaux R étant choisis indépendamment dans la classe formée par les groupes alkyles, alcényles, aryles, arylalkyles, époxy, éthers, alkylamides, alkylamines et chaque OR' est un groupe alcoxy ;
en présence de
(C) une quantité catalytique d'un catalyseur basique, pour produire une résine d'organosilicone alcoxylée ;

(II) ensuite, neutraliser le catalyseur basique par addition d'un acide au produit réactionnel des composants (A), (B) et (C), et
(III) séparer la résine alcoxylée des produits réactionnels restants.

2. Le procédé de la revendication 1, dans lequel ladite résine d'organosilicone MQ (A) a un poids moléculaire moyen en nombre compris entre 2200 et 7000. 45
3. Le procédé de la revendication 2, dans lequel la résine d'organosilicone alcoxylée a un poids moléculaire moyen en nombre qui est inférieur au poids moléculaire moyen en nombre du composant (A) de départ. 50
4. Le procédé de la revendication 1, comprenant de plus l'introduction d'un composant (D), un alcool, dans ladite étape de réaction (I). 55
5. Le procédé de la revendication 1, dans lequel ledit catalyseur basique est choisi dans la classe formée

par NaOH, KOH, NaOCH₃, LiOH, le *tert*-butylate de potassium, LiOCH₃, KOCH₃, le silanolate de sodium, l'éthanolamine et le fluorure de tétrabutylammonium.

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6. Le procédé de la revendication 1, dans lequel ladite étape de neutralisation (II) est effectuée en ajoutant un chlorosilane au produit réactionnel des composants (A), (B) et (C).

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7. Le procédé de la revendication 4, comprenant de plus l'étape consistant à (III) éliminer ledit alcool (D) pendant ladite étape de réaction (I).

8. Les résines d'organosilicone alcoylée pouvant être obtenues par le procédé des revendications 1 à 7.

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